

## Development of a "Spot-Application" Tool for Rapid, High-Resolution Simulation of Wave-Driven Nearshore Hydrodynamics

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Award Number: N00014-13-1-0624

### LONG-TERM GOALS

This project is driven by the desire to simulate wave-driven process in large domains with fine-resolution, while including tide, river, and wind forcings that exist across multiple orders of magnitudes of spatial scales. We aim to explicitly couple large-scale flow models, such as Delft3D, with our developed Boussinesq-type model. The vision of this project is to develop an operational tool for the prediction of O(1 m) resolution hydrodynamics in the coastal zone.

### OBJECTIVES

The targeted objectives for this project are as follows:

- Identify a particular location, such as a beach, river mouth, inlet, or harbor for which detailed predictions of wave height, currents, and transport are needed
- Extract the 3D current and density fields in the area from an existing Delft3D simulation. This information will be used as the background current/density field, which the waves interact with through the domain
- Obtain wave spectra and wind information near the location, either from in-situ measurements or large-scale wave models. This information will be used to drive the offshore wave boundary condition.
- Execute the Boussinesq simulation using the above information, and extract the desired information (e.g. Hmax maps, currents, etc.)

Such a tool could be used to simulate particular “spots” along the coastline where high-resolution wave detail is desired, using output from an operational model to drive the background current and boundary conditions.

### APPROACH

Our goal is to develop a validated and benchmarked model to look at nonlinear wind wave evolution in sheared and stratified nearshore environments with large-scale (10-100+ km<sup>2</sup> horizontal) domains and

<b>Report Documentation Page</b>			Form Approved OMB No. 0704-0188	
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1. REPORT DATE <b>30 SEP 2013</b>	2. REPORT TYPE	3. DATES COVERED <b>00-00-2013 to 00-00-2013</b>		
4. TITLE AND SUBTITLE <b>Development of a 'Spot-Application' Tool for Rapid, High-Resolution Simulation of Wave-Driven Nearshore Hydrodynamics</b>			5a. CONTRACT NUMBER	
			5b. GRANT NUMBER	
			5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)			5d. PROJECT NUMBER	
			5e. TASK NUMBER	
			5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>University of Southern California,Sonny Astani Department of Civil and Environmental Engineering,Los Angeles,CA,90089</b>			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSOR/MONITOR'S ACRONYM(S)	
			11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release; distribution unlimited</b>				
13. SUPPLEMENTARY NOTES				
14. ABSTRACT				
15. SUBJECT TERMS				
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>Same as Report (SAR)</b>	18. NUMBER OF PAGES <b>4</b>
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>	19a. NAME OF RESPONSIBLE PERSON	

fine resolution ( $\sim 1$  m horizontal). The theory to tackle this problem is already developed, but requires further validation and numerical implementation, and these are our two main scientific interests.

The numerical tool must have the ability to be applied for domains on the scale of  $100 \text{ km}^2$  horizontal. This is not a simple request for a model that requires a horizontal resolution on the order of a few meters to properly resolve the wind waves. An optimum approach is to implement a hybrid/coupling approach, wherein different models with various resolutions and physical approximations are meshed together (e.g. Sitanggang & Lynett, 2009; Son et al., 2011). For this study, an ideal model to match with the Boussinesq-type theory would be one which can simulate sheared and stratified currents due to large-scale (non-wave) forcings. Direct coupling the Boussinesq-type wave model with larger-scale tools such as DEFLT3D would permit the efficient use of the high-resolution wave model, but also include regional forcing due to tides, rainfall, wind, and river flow.

Our initial focus has been on explicit coupling of the Boussinesq-type model with the other hydrodynamic “flow” models used in existing ONR efforts. We have utilized DEFLT3D on this component. Due to the very different physical approximations and computational needs between the two sets of models (the Boussinesq-type and the DEFLT3D model), two-way coupling may not be feasible. Thus we are developing a one-way coupling methodology, as shown in Figure 1, where:

- the DEFLT3D model is run first, without any wave effects included
- the 3D current and density field predicted by DEFLT3D is imported into the Boussinesq-type model as an external, background flow field, following the theory in Son & Lynett (2013)
- The Boussinesq-type model is run, where the simulated waves “feel” the effects of the current and density field provided by DEFLT3D

The above approach is a very efficient method for multi-scale, multi-model simulation, and allows for resolution of wave-driven processes with  $O(1 \text{ m})$  resolution while including the regional / basin-scale forcing. Once developed, the hybrid model will be used to simulate the waves and flow at field sites with available measured field data. With the field-data comparison, the fully benchmarked and validated numerical tool will be applicable to a wide-range of nearshore processes and could be utilized at coastal areas worldwide.

Simultaneous to this coupling effort, we will investigate methods to include wind stress effects on the waves in the Boussinesq model; on the large spatial scales we plan to investigate, wind effects may not be negligible on the waves and currents. Initial efforts in this area have been completed by Chen et al. (2004). In the past year, Lynett’s research group has been working to develop a surface boundary layer formulation appropriate for integration with Boussinesq-type models, similar to our work on bottom boundary layers (Kim et al., 2009). These efforts have shown some promise in capturing the vertical structure of wind-induced currents, and will be coupled with nonlinear waves here.

## WORK COMPLETED

This project was initially funded in June of 2013 (start date of 6/11/13), and thus limited work has been completed during the initial four months of the project. To date, we have further developed the Boussinesq-type wave model with the ability to ingest a current field from DEFLT3D. Efforts have focused on computational efficiency, such as a reduction in the complexity of the model, and

conversion of the code to run on GPU's. In addition, the PhD student working on this project has started testing with DELFT3D, and will soon be running simulations with real bathymetry, such as New River Inlet.

## **RESULTS**

As noted above, the project was initiated less than four months ago, and there are not yet any substantial or complete results of the effort.

## **IMPACT APPLICATIONS**

The overall objective of this project is to setup the modeling system for operational-like usage. A simple model interface will be created such that a “complete” tides+waves simulation can be run with only the specification of the date/time (to provide the DELFT3D tidal forcing) and an offshore wave & wind condition. It is the hope and expectation that the end result of this effort will provide a demonstration of the operational usability of Boussinesq-type models.

## **RELATED PROJECTS**

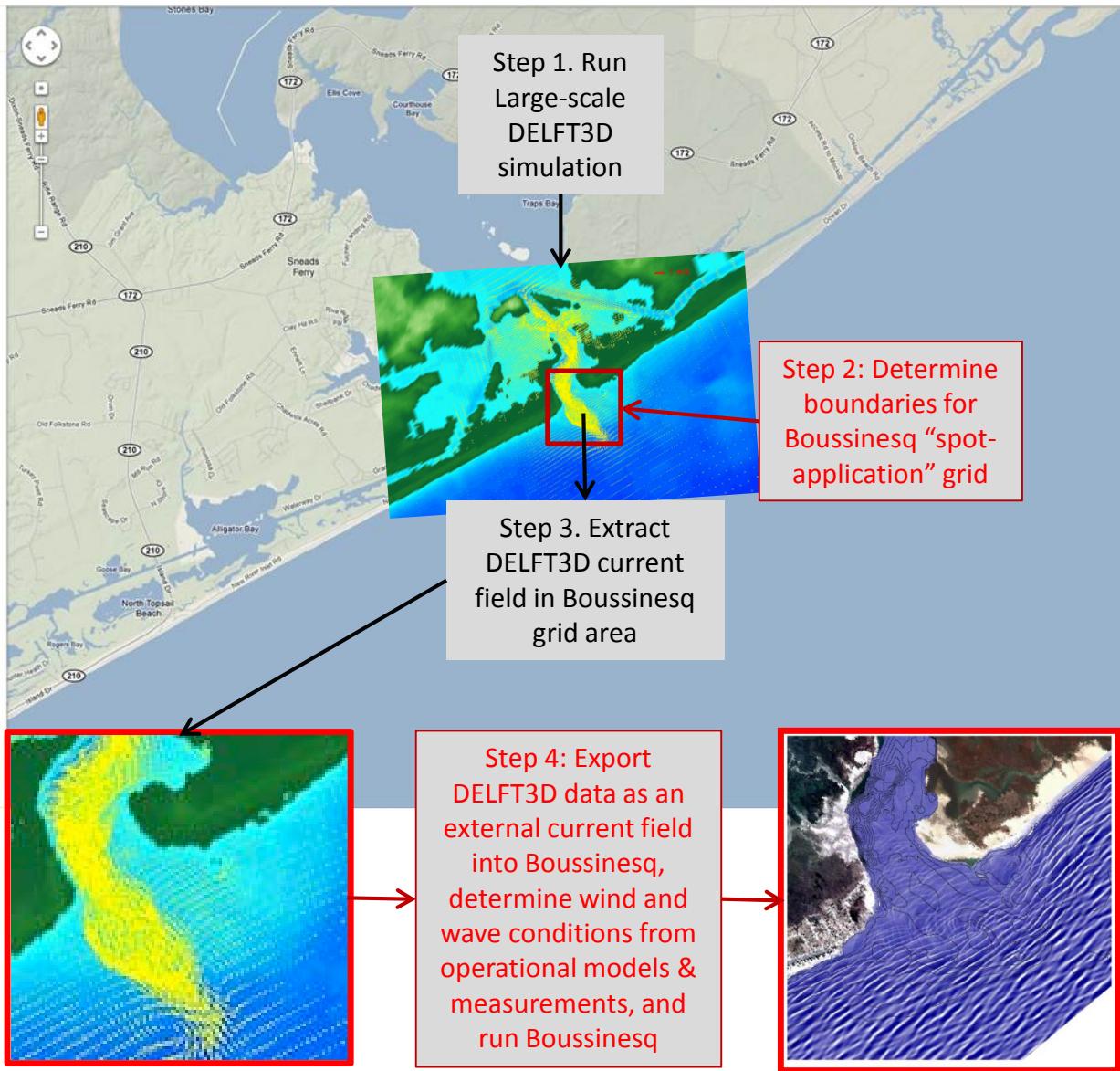
This modeling ability to be developed in this project will be useful for simulating the data recorded during the RIVET I and II field surveys.

## **REFERENCES**

- Chen, Q., Kaihatu, J. M. and Hwang, P. A., 2004. Incorporation of the wind effects into Boussinesq wave models. *Journal of Waterway, Port, Coastal and Ocean Engineering*. 130 (6): 312-321.
- Kim, D.-H., Lynett, P., and Socolofsky, S. (2009) A Depth-Integrated Model for Weakly Dispersive, Turbulent, and Rotational Fluid Flows, *Ocean Modelling*, 27(3-4), p. 198-214." *Journal of Waterway, Port, Coastal, and Ocean Engineering* (ASCE), v. 126(6), p. 314-322.
- Sitanggang, K. and Lynett, P. (2005). "Parallel Computation of a Highly Nonlinear Boussinesq Equation Model through Domain Decomposition." *International Journal for Numerical Methods in Fluids*, v. 49(1), p. 57-74.
- Son, S., Lynett, P., and Kim, D.-H., "Nested and Multi-Physics Modeling of Tsunami Evolution from Generation to Inundation," *Ocean Modelling*, v. 38 (1-2), p. 96-113, doi: 10.1016/j.ocemod.2011.02.007, 2011.

## **PUBLICATIONS**

None yet to date



**Figure 1. Procedure for coupling DELFT3D and Boussinesq model for combined circulation and wave simulations.**